Management of dandelion to supplement control of western flower thrips (Thysanoptera: Thripidae) in apple orchards

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ABSTRACT

We evaluated whether management of the broadleaf weed dandelion, *Taraxacum officinale* F.H. Wigg. aggr., affected damage to apples by western flower thrips (*Frankliniella occidentalis* (Pergande)). Four commercial apple orchard blocks in central Washington having high densities of dandelion were monitored over a 3-yr period. Herbicides were applied to the drive rows in one-half of each orchard for each year of the study. A 92% reduction in dandelion densities in the low-weed plots was achieved by the third year of the experiment. The number of thrips per dandelion plant did not change as dandelions became less numerous. This resulted in an overall reduction in western flower thrips per unit area on dandelions throughout the course of the trial. However, the number of western flower thrips in the apple flowers and shoots were not affected by the treatment. Estimated western flower thrips population density per ha on apple and dandelion indicated that dandelions harboured a much smaller pool of western flower thrips in comparison to apple. No significant reduction in fruit injury was detected in any year. Thus, reduction or elimination of dandelion from the orchard floor appears to be of limited value in managing western flower thrips in apple orchards.

INTRODUCTION

Western flower thrips, *Frankliniella occidentalis* (Pergande), is a sporadic, direct pest of apple (Beers *et al.* 1993). The most conspicuous injury consists of an oviposition puncture, which leaves a small, rugose scar, and a series of white spots surrounding it, commonly known as pansy spot (Newcomer 1921). Injury is most apparent on green or blush cultivars (Madsen and Jack 1966). Densities of adult thrips in apple blossom clusters increase in late April and May as the flowers open; oviposition in fruit occurs from the end of bloom until fruit reaches 30 mm in diameter (Cockfield *et al.* 2007a).

Beginning with the earliest investigations of western flower thrips in apple orchards, broadleaf plants in the groundcover have been assumed to greatly influence the population dynamics of this pest. Venables (1925) collected western flower thrips from tumbling mustard (*Sisymbrium altissimum* L.), a common weed, and alfalfa, *Medicago sativa* L., from apple orchards in British Columbia. These host plants harboured the pest throughout the summer. Childs (1927) stated that the choice and management of cover crops is a major component to western flower thrips management. He recommended cultivating or plowing the orchard ground in early spring to eliminate weeds and to disrupt overwintering thrips in the soil. After the practice of growing cover crops such as alfalfa was no longer common, Madsen and Jack (1966) determined that dandelion, *Taraxacum officinale* F.H. Wigg. aggr., was the most abundant understory host of western flower thrips before and after apple bloom, and wild mustard, *Brassica kaber* (DC.) L.C. Wheeler, and asparagus, *Asparagus officinalis* L., were important alternate hosts in the summer. Pearsall and Myers (2000, 2001) found that not only did a number of broadleaf weeds

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harbour western flower thrips, but orchards with the highest population of weeds had some of the highest numbers of western flower thrips caught in sticky traps.

Two recent experiments done on groundcover management have shown mixed results. Hubscher (1983) found that a temporary perturbation, such as mowing dandelions in spring (intended to redirect pollinators to apple blossoms) had no measurable effect on the population of western flower thrips in apple, or damage to fruit. Cossentine *et al.* (1999) showed that elimination of weeds such as dandelion in small plots reduced thrips populations in trees, but the effect was temporary. The magnitude of the effect may have been limited by the temporal and spatial scale of both studies; thus, a more substantial, permanent effect may result from eliminating weeds for a number of seasons in larger orchard blocks. If successful, this method could reduce the need to control western flower thrips around the bloom period, or reduce fruit damage as part of a multi-tactic IPM program. The purpose of this investigation was to determine the effect of a cultural control method, long-term management of dandelion, on populations of western flower thrips in large blocks of commercial apple orchards and to determine the effect of thrips population changes on fruit damage.

MATERIALS AND METHODS

Site Description. This experiment was conducted over the course of three years in four commercial apple orchards near the towns of Bridgeport, Brewster, Pateros, and Quincy in Washington State, U.S.A. The orchards were selected because of a history of significant thrips damage to fruit and for their high densities of dandelions ($>10/m^2$). Trees in the Bridgeport orchard block were cv. 'Granny Smith', while the Brewster and Pateros blocks were cv. 'Braeburn'. The Quincy block was planted with alternating two rows of cv. 'Fuji' and 'Braeburn'. Trees were 7-15 yr old. Each block was approximately 2-4 ha and was surrounded by other orchards. There were two treatments: 1) low-weed, where herbicide applications were made in the drive rows (the section of the orchard floor between the tree rows left as mixed grass and weed groundcover to facilitate use of equipment) and 2) high-weed (drive rows untreated with herbicides). Each of the four orchards was divided in half, and treatments assigned randomly, with each site serving as a replicate.

Herbicides. A vegetation-free strip about 2 m wide was maintained beneath the trees in both halves of the block. All orchards in the study had a similar program for weed control in the vegetation-free tree rows. Pre-emergent herbicides, and sometimes 2,4-dichlorophenoxyacetic acid (2,4-D), were applied in early spring, followed by individual sprays or mixtures of paraquat, 2,4-D, and glyphosate after bloom. If necessary, repeat applications were made in June.

The drive rows of low-weed plots were sprayed with 1.1-1.6 kg AI/ha of 2,4-D (Weedar 64, Nufarm Inc., St. Joseph, MO) + 370 ml/100 litres of R11 surfactant (Wilbur-Ellis Co., San Francisco, CA). One or two applications were made in the spring with a weed sprayer calibrated to deliver 234 litres/ha. Any surviving weeds were treated individually with a 9% vol:vol solution of 2, 4-D with a 15.1 litre backpack sprayer (Wil-Gro, Wilbur-Ellis Co., San Francisco, CA).

Insecticides. Insecticides applied for apple pests in a given site were the same across the entire block (high-weed and low-weed plots). Densities of lepidopteran pests were generally low in the study orchards, and required minimal treatment. These pests were managed with applications of chlorpyrifos at delayed dormant, spinosad at petal fall, and azinphos-methyl or methoxyfenozide during early summer. Because of the history of fruit injury, growers applied formetanate hydrochloride to control western flower thrips at full bloom every year.

Sampling Methods. Dandelion densities were sampled by counting the numbers of plants in a marked 1 m^2 area in the drive rows. Ten randomly selected areas were marked in the middle row of each treatment block, with each area separated by about 3-5 m. Within these areas, dandelion plants (both total numbers and those in flower) were counted monthly from March or April through October.

Thrips densities were sampled monthly on four flowering and four vegetative dandelion plants per plot. All thrips samples were taken the same time of mid-day in each of the paired plots, although the time differed between sites. Dandelion plants (outside the m^2 marked areas) were severed at ground level and placed in self-sealing plastic bags.

Thrips were sampled in the blossoms and vegetative shoots of apple trees. Blossom samples were taken during full bloom (April or May) about one day before insecticides were applied. Twenty-five open apple blossoms were selected from eight trees randomly chosen in the middle row of the plot. The blossoms were clipped off and placed in self-sealing plastic bags. The area sampled was at least 30 m away from the edges of the plots. In the third and final year, the sample size was increased to 150-300 flowers per tree. Thrips in vegetative shoots were sampled monthly after the termination of bloom. The tips (3 cm in length) of 10 growing shoots were collected from each of eight trees.

Thrips samples from dandelion and apple were stored under refrigeration and processed the day after collection. Thrips were separated from plant material by filling the bag with water, adding a few drops of liquid detergent, and agitating for several minutes. Thrips and plant material were separated from the soapy water by pouring through two sieves (Hubbard Scientific Co., Northbrook, IL). The larger sieve (#10, 0.25-mm mesh) trapped most of the plant material, and the finer sieve (#230, 0.0014-mm mesh) trapped the thrips. Thrips were then rinsed into a vial of 50% ethanol. Specimens were first examined under a dissecting microscope. All *Frankliniella* adults were slide-mounted in PVA Mounting Medium (BioQuip Products, Inc., Rancho Dominguez, CA) for identification to species. A reference collection was sent to Cheryl O'Donnell, Department of Entomology, University of California, Davis, CA, who confirmed the identity of species. Only numbers of *F. occidentalis* adults were recorded. The means of the samples taken per plot were used in the analyses. All data were expressed as thrips per dandelion plant, apple flower, or apple shoot. Thrips per dandelion plant during peak dandelion flowering were averaged over the three years of the study.

Population Estimates. The monthly population density of western flower thrips per m^2 in dandelions in the drive rows was estimated by multiplying the average number of thrips per sampled nonflowering and flowering dandelions by the average number of dandelions of each type per m^2. Estimates were also summed for each replicate over the three years of the study. The estimate at peak dandelion bloom, just before or during apple bloom, was then used to calculate the number of western flower thrips on dandelion on a per-hectare basis. This was done by multiplying the mean number of thrips per m^2 by the number of m^2 of drive rows in each ha. Similarly, estimates were obtained for western flower thrips per ha in apple flowers. Flower densities were estimated by counting all blossoms on 10 trees per plot. Mean flowers per tree were calculated for each site, then converted to means per ha based on the tree density per ha. Flowers per ha were multiplied by the mean number of thrips per flower.

Data Analysis. The experimental design was a randomized complete block with the four orchards serving as replicates. The effects of herbicide treatment and month on dandelion densities were assessed using a two-way analysis of variance having repeated observations through time (=month). The analyses were done in SAS using PROC MIXED (SAS Institute 2002). Separate analyses were done for each of the three years of the study. We used a square root transformation on the count data before each analysis to meet ANOVA assumptions. In the event of a significant treatment × month interaction, tests on simple effects of treatment and month were done using the SLICE command. Analyses of flowering dandelions were done only for the sampling date with the highest number of flowering plants. Comparisons of flowering dandelions were made by year using paired t-tests (SAS Institute 2002). Data for thrips densities, whether monthly, averaged, or summed measurements, were analyzed by date using ANOVA. Treatment means were separated using a LSD test (high-weed vs low-weed, α=0.05). Data for proportion (p) of fruit with pansy spot injury were first transformed by arcsine(square root (p+0.001)), then analyzed using ANOVA (SAS Institute 2002).

RESULTS AND DISCUSSION

Dandelion Densities. Densities of total dandelions were high in both high-weed and low-weed treatments at the start of the experiment (Fig. 1A). A few other broadleaf weeds also occurred in the orchard blocks, most notably alfalfa, but population densities of these other weeds were zero in the randomly-sampled areas. All perennial and annual broadleaf weeds were affected by the herbicides and were reduced in the low-weed plots, which resembled manicured lawns. The treatment × month interaction terms were highly significant in 2003 (F=4.10; df=7, 42; P=0.0016) and 2004 (F=3.39; df=8, 48; P=0.0037), and significant in 2005 (F=2.37; df=7, 42; P=0.039), thus we examined the simple effects tests (herbicide effect for each month separately). Treatment differences became significant by July of 2003, with 17.1 (± 11.6 SEM) dandelions/m^2 in the low-weed plots versus 66.1 (± 23.4) in the high-weed plots. These differences were sustained through the remainder of the year. Treatment differences were only marginally significant for the first two months of 2004 (P<0.10), but were re-established by May with lower dandelion densities in the low-weed plots throughout the remainder of the year (P<0.001). Treatment differences were significant throughout 2005 (P<0.001), which was also reflected in the main effect treatment means for this year (low-weed plots, 2.3 ± 0.3; high-weed plots, 29.4 ± 2.4 dandelions/m^2; F=75.79; df=1, 6; P=0.0001). The treatment differences in 2005 reflected a 92% reduction in dandelion densities in the low-weed plots relative to the high-weed plots.

Dandelions flowered primarily in April or May; very few plants flowered in the summer and fall (Fig. 1B). During the peak period, flowering dandelion density was not significantly different in the low-weed (5.5 ± 1.6) and high-weed (7.5 ± 3.4) plots in 2003 (t=0.60, df=3, P=0.59). The effect of the herbicide applications was more clearly seen in 2004 (low weed, 2.8 ± 1.8; high weed, 10.1 ± 3.1; t=3.74, df=3, P=0.03) and 2005 (low weed, 0.3 ± 0.1; high weed, 8.0 ± 1.8; t=4.36, df=3, P=0.02).

Thrips in Dandelions. The estimated population density of thrips on dandelion in the drive rows (on a per m^2 basis) generally increased in the high-weed blocks in late spring, and peaked in April (2005), during which maximum dandelion bloom occured, or June (2003, 2004) (Fig. 1C). Adult thrips decreased in numbers by July and August and remained at low densities in the fall. Estimated densities of thrips were highly variable between sites and monthly comparisons were not significantly different; however, there were higher thrips densities in dandelions in the high-weed plots (33.7 ± 11.0) than in the low-weed plots (2.9 ± 0.7) when the estimates were summed over the three years (F=7.79; df=1,6; P=0.031).

The three-year average of thrips per flowering dandelion plant was 0.22 in high-weed and 0.33 in low-weed blocks, while thrips per vegetative plant was 0.04 in high-weed and 0 in low-weed blocks during peak dandelion flowering (F=0.38; df=1,6; P=0.56,). No difference in thrips density (on a per plant basis) was found in flower-

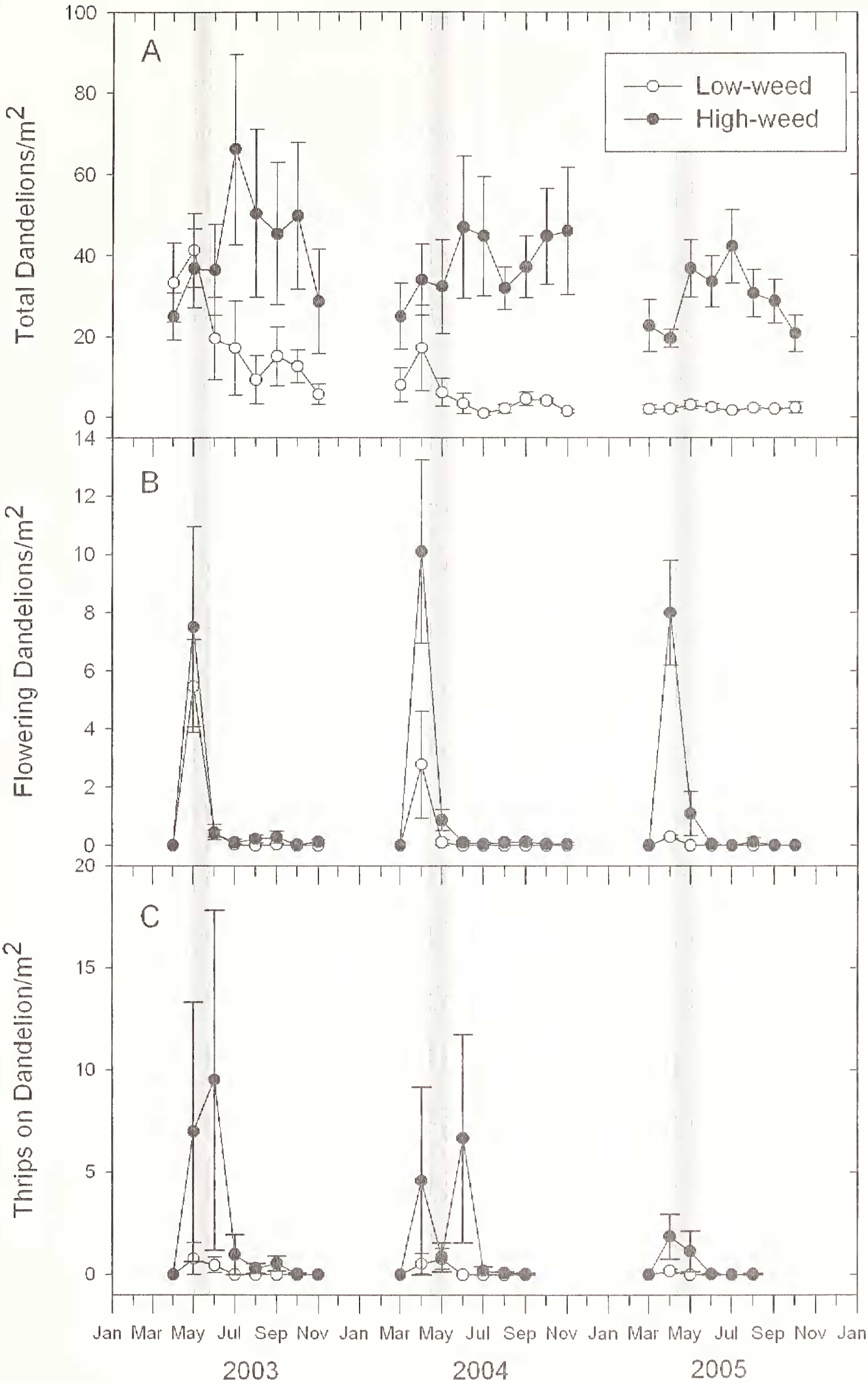

Figure 1. (A) Dandelions per m^2 area of orchard ground in low-weed and high-weed orchard blocks. (B) Blooming dandelions per m^2 area of orchard ground in low-weed and high-weed orchard blocks. (C) Western flower thrips population estimates (adults per m^2) on dandelions in low-weed and high-weed orchard blocks. Symbols are means, error bars are SEM. Grey bars indicate the period of apple bloom.

ing dandelions from either low-weed or high-weed blocks at any sample period. Therefore, thrips population density per dandelion was largely not influenced by dandelion density. The reduction of thrips per area was determined by reduction of dandelions.

Thrips in Apple. All of the thrips specimens collected from apple flowers in the three years of the experiment were western flower thrips, *F. occidentalis*. Western flower thrips has been the dominant thrips species collected from apple flowers in the inland Pacific Northwest (Venables 1925, Childs 1927, Madsen and Jack 1966, Cockfield *et al.* 2007b). In contrast, apple shoots and dandelions contained a mixture of species, including *F. occidentalis*. Western flower thrips accounted for about 38% of the thrips in apple shoots sampled in Washington state (Cockfield *et al.* 2007b). No significant differences in adult western flower thrips populations were found in any of the apple flower or shoot samples from high-weed and low-weed plots, even in 2005, after dandelion numbers had been greatly reduced in the low-weed plots (Table 1). Thrips densities at full apple bloom were average compared with other samples in Washington (Miliczky *et al.* 2007). Thrips in the apple shoots may contribute to fruit injury in late May, but more likely sustain the population in the orchard throughout the summer and from year to year (Cockfield *et al.* 2007a, 2007b). While thrips densities provide a useful measure of the treatment effects, the critical measurement for the purposes of management is fruit damage. In the study orchards, an insecticide treatment was inadequate to prevent fruit injury, indicating the need for an additional management tactic. However, significant reductions in numbers of dandelions did not correspond with a significant reduction in fruit injury in any of the three years (Fig. 2). Thus the effort and time investment needed to manage broadleaf weeds did not provide a substantial benefit to fruit damage reduction.

One possible explanation for the lack of effect is that thrips moved between high-weed and low-weed plots, in spite of the large size of the experimental plots. A second and more likely explanation is that the potential contribution of western flower thrips from dandelion is relatively small during late spring, when fruit injury occurs. While dandelion flowers often harbour large numbers of thrips, western flower thrips may be <10% of the total individuals present (Cockfield *et al.* 2007b). The per-hectare estimates of thrips densities indicated that 45,000 and 4,000 adult western flower thrips per ha (high-weed and low-weed plots, respectively) occurred on dandelion, compared to estimates of 141,000 and 157,000 thrips per ha, respectively, on apple flowers at peak bloom just before the critical period for fruit damage. The attractiveness of flowering plants to western flower thrips is well established (Terry 1991, 1997). During their bloom periods there were 1.9 million apple blossoms per ha compared with 43,000 dandelion blossoms; even assuming they are equally attractive, the sheer number of apple flowers could be expected to dominate this interaction during the bloom period.

There is ample evidence this highly polyphagous species is abundant in many hosts other than apple, including crop and non-crop plants. Recent studies (Pearsall and Myers 2000, Pearsall and Myers 2001, Cockfield *et al.* 2007b) clarify that in the semi-arid interior fruit growing districts of the Pacific Northwest, multiple species of the native vegetation serve as a host for thrips. Further studies indicate that immigration from the native vegetation may affect thrips density and damage in orchard borders (Miliczky *et al.* 2007). Even though the orchards in this study were not adjacent to native vegetation, it is still potentially a very large source of thrips in the industry. Removal of one relatively small source, dandelion blossoms, would constitute only a minor change in local populations. This, coupled with the large resource constituted by apple blossoms, and to a lesser extent, vegetative tissues, effectively negates any benefit of dandelion removal.

Table 1.
Western flower thrips, mean (SEM), sampled per apple flower and per shoot in high-weed and low-weed treatments[1].

	Low-weed		High-weed			
Date	**Flowers**	**Shoots**	**Flowers**	**Shoots**	***F***	***P***
May 2003	0.148 (0.068)a		0.106 (0.051)a		1.42	0.320
June 2003		0.194 (0.034)a		0.181 (0.041)a	0.15	0.721
July 2003		0.056 (0.030)a		0.069 (0.011)a	0.24	0.658
Aug 2003		0.028 (0.020)a		0.028 (0.020)a	0.0	1.000
Apr 2004	0.035 (0.012)a		0.025 (0.006)a		1.04	0.382
May 2004		0.388 (0.229)a		0.316 (0.126)a	0.43	0.557
June 2004		0.203 (0.123)a		0.121 (0.059)a	1.54	0.303
July 2004		0.156 (0.080)a		0.113 (0.053)a	1.01	0.388
Apr 2005	0.074 (0.027)a		0.089 (0.031)a		4.54	0.123
May 2005		0.028 (0.016)a		0.084 (0.028)a	4.96	0.112
June 2005		0.190 (0.112)a		0.200 (0.122)a	6.00	0.092
July 2005		0.058 (0.011)a		0.058 (0.018)a	0.0	1.000

[1] Means within rows followed by the same letter are not significantly different, LSD test, $\alpha=0.05$. For all analyses, df=1,3.

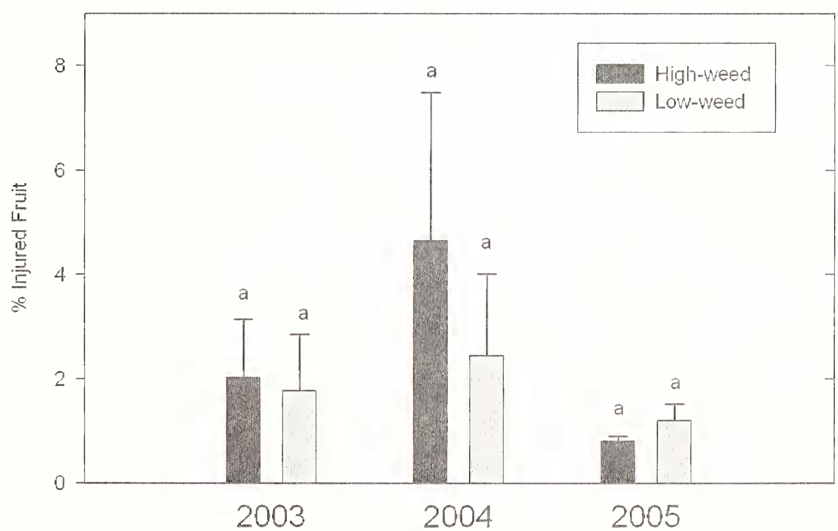

Figure 2. Percentage of fruit with pansy spot in low-weed and high-weed plots. Bars are means, error bars are SEM. Means with the same letter are not significantly different within each year. 2003: F=0.72; P=0.4581. 2004: F=2.33; P=0.2241. 2005: F=1.15; P=0.3625. For all analyses, df=1,3.

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